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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	
Hillegonda Bakker et al.	Confirmation No. 9209
Serial No. 10/500,280	Group Art Unit: 3744
Filed June 28, 2004	Examiner: John F. Pettitt
MULTISTAGE FLUID SEPARATION ASSEMBLY AND METHOD	June 11 , 2009

Mail Stop Appeal
Commissioner for Patents
P.O. Box 1450
Arlington, Virginia 22313-1450

Supplemental Appeal Brief

In response to the Final Office action of October 29, 2008, and a Notification of Non-Compliant Brief mailed June 5, 2009, this Supplemental Appeal Brief is submitted. The present appeal is taken from the action of the Examiner in finally rejecting claims 1-19. The full text of claims 1-19 in the Claims Appendix appended hereto.

Reconsideration of this application in light of this Supplemental Appeal Brief is respectfully requested.

i) Real Party in Interest

The present application is owned by Shell Oil Company, which is the real party of interest in the present appeal.

ii) Related Appeals and Interferences

Appellant is aware of no other appeals or interferences that will affect or be affected by or have a bearing on the Board's decision in the present appeal.

iii) Status of Claims

Claims 1-19 are pending. Claims 1-19 are under final rejection. **Claims 1-19 are appealed.**

iv) Status of Amendments

No amendments after final rejection have been requested.

v) Summary of Claimed Subject Matter

The present invention relates to a multistage fluid separation assembly. The assembly includes a plurality of primary gas cooling devices (which have liquefied and/or solidified condensables enriched fluid outlet, and a secondary fluid separation vessel having a tubular vertical section. The vessel is connected to the condensables enriched fluid outlet of the primary gas cooling devices cooling device(s) via a tangential conduit which injects the condensables enriched fluid tangentially into the tubular section such that a tertiary stream of liquefied and/or solidified condensibles is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank at or near a bottom of the vessel for collecting a tertiary mixture of liquefied and/or solidified condensables. The tank is provided with one or more heaters for heating the tertiary mixture to reduce the amount of solidified condensables and with one or more outlets for discharging the tertiary mixture from the tank. The plurality of liquefied and/or solidified condensables enriched fluid outlets are connected at regular circumferential intervals to the tubular section of the secondary separation vessel and the enriched fluid outlets inject in use condensables enriched fluid in an at least partially tangential direction into the interior of the secondary separation vessel.

The specific invention that is the subject of this Appeal is set out below, as claimed in appealed independent claims 1 and 17. In the following paragraphs, reference numerals, if present, will be presented in **bold**, following the page and line number where the item or feature is disclosed.

Claim 1. A multistage fluid separation assembly comprising: a plurality of primary gas cooling devices (page 13 line 19 **31 and 31A**), each of which has a

liquefied and/or solidified condensables enriched fluid outlet (page 14, lines 1-2, **33 and 33A**); and, a secondary fluid separation vessel (page 14, lines 3-4 **32**) having a tubular section of which a central axis has a substantially vertical or tilted orientation (page 14, lines 4-5, **41**), which vessel is connected to said condensables enriched fluid outlets of said primary gas cooling devices, wherein during normal operation of the vessel the condensables enriched fluid is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary stream-of liquefied and/or solidified condensables is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank (page 14, line 25, **49**) at or near a bottom of the vessel for collecting a tertiary mixture of liquefied and/or solidified condensables, which tank is provided with one or more heaters (page 15, line 15, **50**) for heating the tertiary mixture to reduce the amount of solidified condensables and with one or more outlets for discharging the tertiary mixture from the tank; wherein the plurality of liquefied and/or solidified condensables enriched fluid outlets are connected at regular circumferential intervals to the tubular section of the secondary separation vessel and the enriched fluid outlets inject in use condensables enriched fluid in an at least partially tangential direction into the interior of the secondary separation vessel.

Claim 17. A method of separating condensable components from a fluid mixture in a multistage fluid separation assembly, the method comprising:

injecting the fluid mixture into a plurality of primary gas cooling devices (page 13 line 19 **31 and 31A**) in which the fluid mixture is expanded and cooled and condensable components are liquefied and/or solidified and in each primary gas cooling device a stream of condensables enriched fluid components is fed into a secondary fluid outle t(page 14, lines 1-2, **33 and 33A**); and

injecting the stream of condensables enriched fluid components into a secondary fluid separation vessel (page 14, lines 3-4 **32**) having a tubular section of which a central axis has a substantially vertical or tilted orientation (page 14, lines 4-5, **41**) and in which the condensables enriched fluid stream is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary mixture of liquefied and/or

solidified condensables is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank (page 14, line 25, **49**) at or near a bottom of the vessel, in which tank the tertiary mixture of liquefied and/or solidified condensables is collected and heated to reduce the amount of solidified condensables and from which tank liquid and/or solidified components are discharged through one or more outlets; wherein a plurality of secondary fluid injection outlets are connected at regular circumferential intervals to the tubular section of the secondary separation vessel, and the enriched fluid outlets inject the condensables enriched fluid in an at least partially tangential direction into an interior of the secondary separation vessel.

(vi) Grounds of Rejection to be Reviewed on Appeal

Whether claims 1-7, 12 and 16-19 are obvious over Atkinson (US 2,683,972) (hereafter Atkinson) in view of Engle (US 3,259,145) (hereafter Engle) .

Whether claim 8 is obvious in over Atkinson in view of Engle and Coggins et al. (US 4,208,196) (hereafter Coggins).

Whether claims 9 and 11 are obvious over Atkinson in view of Engle and Alferov et al. (US 6,372,019) (hereafter Alferov).

Whether claim 10 is obvious in over Atkinson in view of Engle, Coggins and Skrebowski.

Whether claims 13, 14, and 15 are obvious over Atkinson in view of Engle and Coggins et al. (US 4,208,196) (hereafter Coggins).

Claims 1-19 stand or fall together.

(vii) Argument

(a) Whether claims 1-7, 12 and 16-19 are obvious over Atkinson (US 2,683,972) (hereafter Atkinson) in view of Engle (US 3,259,145) (hereafter Engle):

Applicants dispute this ground of rejection because the combination of references does not teach an apparatus meeting the limitations of claims. Each of the claims requires that a primary gas cooling device that has a liquefied and/or solidified condensables **enriched** fluid outlet (or stream) which passes to a secondary fluid separation vessel. The cold liquid fluid outlet of the vortex tube of Atkinson is cited as this element. The Examiner

point to Atkinson's statement that water condenses along with condensable hydrocarbons as a result of reduced temperatures at cold end (14:column 3, lines 1-10).

Atkinson's cold outlet may contain condensables, but it does not contain a stream enriched in condensables. A vortex tube separates a high pressure vapor into two lower pressure streams, one hot and one cold stream. The cold stream is not "enriched" in condensables. In fact, the hot stream may contain a greater concentration of condensables (see US patent 6,932,858, "Vortex Tube System and Method for Processing Natural Gas" at column 2, lines 3-8, "**It has also been shown that the hot stream exists in a somewhat richer state, that is, more heavy components than the cold stream**…"). US patent 6,932,858 is included in the attached Evidence Appendix. The cold outlet stream from a vortex tube is therefore not a stream enriched in condensables, and this element is therefore not present in the art cited art. An examination of the workings of a vortex tube, for example figure 1 of US patent 6,932,858, and the accompanying text, clearly supports the statement that any change in compositions within a vortex tube would be enriching the hot stream in condensable material, not the cold stream. The cold stream 20 swirls inside of the hot stream 19, which is swirling and traveling axially in the opposite direction, toward the hot stream outlet 12. Liquids or solids in the swirling cold stream would tend to be forced outward by centrifugal force back into the hot stream, where they would be vaporized, and a portion of this material would then exit as a component of the hot stream.

The hot stream exiting a vortex tube may be a "condensables enriched stream", but the hot stream of Atkinson does not meet the limitations of the present claims because it is not, among other things, "induced to swirl around the central axis of the tubular section of the vessel such that a tertiary stream-of liquefied and/or solidified condensables is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank…" as required by the present claims.

Atkinson discloses an apparatus that separates condensables from a stream by using a vortex tube to generate a hot stream, and a cold steam, the cold stream containing condensables. The condensables are then separated from the cold stream by centrifical separation. The hot stream and cold stream are recombined to produce a stream that is reduced dew point. Some heat from the hot stream is also used to melt hydrates, and by

exchanging heat with the cold hydrates, more water or condensables condense from the hot stream and are separated.

For the foregoing reasons, Applicants submit that this ground of rejection is in error.

(b) Whether claim 8 is obvious in over Atkinson in view of Engle and Coggins et al. (US 4,208,196) (hereafter Coggins):

Applicants dispute this ground of rejection because the combination of references does not teach an apparatus meeting the limitations of claims. Claim 8, dependent from claim 1, requires that a primary gas cooling device that has a liquefied and/or solidified condensables **enriched** fluid outlet (or stream) which passes to a secondary fluid separation vessel. This element is not added to the combination by Coggins, and therefore is lacking in the cited references for the same reasons stated in (a) above.

(c) Whether claims 9 and 11 are obvious over Atkinson in view of Engle and Alferov et al. (US 6,372,019) (hereafter Alferov):

Applicants dispute this ground of rejection because the combination of references does not teach an apparatus meeting the limitations of claims. Claims 9 and 11, both dependent from claim 1, requires that a primary gas cooling device that has a liquefied and/or solidified condensables **enriched** fluid outlet (or stream) which passes to a secondary fluid separation vessel. This element is not added to the combination by Alferov, and therefore is lacking in the cited references for the same reasons stated in (a) above.

(d) Whether claim 10 is obvious in over Atkinson in view of Engle, Coggins and Skrebowski:

Applicants dispute this ground of rejection because the combination of references does not teach an apparatus meeting the limitations of claims. Claim 10, dependent from claim 1, requires that a primary gas cooling device that has a liquefied and/or solidified condensables **enriched** fluid outlet (or stream) which passes to a secondary fluid separation vessel. This element is not added to the combination by either Engle, Coggins nor Skrebowski, and therefore is lacking in the cited references for the same reasons stated in (a) above.

(e) Whether claims 13, 14, and 15 are obvious over Atkinson in view of Engle and Coggins et al. (US 4,208,196) (hereafter Coggins):

Applicants dispute this ground of rejection because the combination of references does not teach an apparatus meeting the limitations of claims. Claims 13, 14, and 15, all dependent from claim 1, requires that a primary gas cooling device that has a liquefied and/or solidified

condensables **enriched** fluid outlet (or stream) which passes to a secondary fluid separation vessel. This element is not added to the combination by either Engle nor Coggins, and therefore is lacking in the cited references for the same reasons stated in (a) above.

It is therefore submitted that claims 1-19 are patentable over the art of record. Accordingly, Applicants respectfully request reversal of the rejections and allowance of the rejected claims.

Respectfully submitted,

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Claims Appendix

1. (Previously Presented) A multistage fluid separation assembly comprising:

a plurality of primary gas cooling devices each of which has a liquefied and/or solidified condensables enriched fluid outlet; and,

a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation, which vessel is connected to said condensables enriched fluid outlets of said primary gas cooling devices, wherein during normal operation of the vessel the condensables enriched fluid is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary stream-of liquefied and/or solidified condensables is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank at or near a bottom of the vessel for collecting a tertiary mixture of liquefied and/or solidified condensables, which tank is provided with one or more heaters for heating the tertiary mixture to reduce the amount of solidified condensables and with one or more outlets for discharging the tertiary mixture from the tank;

wherein the plurality of liquefied and/or solidified condensables enriched fluid outlets are connected at regular circumferential intervals to the tubular section of the secondary separation vessel and the enriched fluid outlets inject in use condensables enriched fluid in an at least partially tangential direction into the interior of the secondary separation vessel.

2. (Previously Presented) The fluid separation assembly of claim 1, wherein the liquid collecting tank comprises an upper liquid outlet for low density liquid components and a lower liquid outlet for high density liquid components.

3. (Previously Presented) The fluid separation assembly of claim 1, wherein the tubular section of the secondary separation vessel is equipped with a tertiary gas outlet conduit having an inlet which is located at or near the central axis of the tubular section.

4. (Previously Presented) The fluid separation assembly of claim 3, wherein the secondary separation vessel has a dome or disk shaped top which is mounted on top

of the tubular section and the tertiary gas outlet conduit is arranged substantially co-axial to the central axis of the tubular section and passes through said top.

5. (Previously Presented) The fluid separation assembly of claim 1, wherein the liquefied and/or solidified condensables enriched fluid outlet of at least one primary gas cooling devices injects in use the condensables enriched fluid in an at least partially tangential direction into the tubular section of the secondary separation vessel.

6. (Previously Presented) The fluid separation assembly of claim 5, wherein the central axis of the tubular section of the secondary separation vessel has a substantially vertical orientation and said plurality of primary gas cooling devices each of which has a liquefied and/or solidified condensables enriched fluid outlet inject in use condensables enriched fluid in an at least partially tangential and partially downward direction into the interior of the secondary separation vessel.

7. (Previously Presented) The fluid separation assembly of claim 1, wherein the liquid collecting tank is formed by a cup-shaped tubular lower portion of the secondary separation vessel which is substantially co-axial to the central axis and has a larger internal width than the upper portion of the vessel.

8. (Previously Presented) The fluid separation assembly of claim 1, wherein a vortex breaker is arranged in the interior of the secondary separation vessel between the lower end of the tubular section and the liquid collecting tank.

9. (Previously Presented) The fluid separation assembly of claim 1, wherein the assembly is provided with one or more ultrasonic vibration transducers for imposing ultrasonic vibrations on one or more components of the assembly to inhibit deposition of solidified condensables, such as ice, wax and/or hydrates, within the assembly.

10. (Previously Presented) The fluid separation assembly of claim 8, wherein at least one of the plurality of primary gas cooling devices, each of which has a liquefied and/or solidified condensables enriched fluid outlet and the vortex breaker, are equipped with ultrasonic vibration transducers.

11. (Previously Presented) The fluid separation assembly of claim 9, wherein the ultrasonic vibration transducers are designed to vibrate in use one or more components of the assembly at a frequency between 20 and 200 KHz.

12. (Previously Presented) The fluid separation assembly of claim 1, wherein the liquid collecting tank is provided with a grid of heating tubes which are designed to heat the liquid and solid fluid mixture in the tank to a temperature of at least 15 degrees Celsius.

13. (Previously Presented) The fluid separation assembly of claim 1, wherein at least one of the plurality of primary gas cooling devices, each of which has a liquefied and/or solidified condensables enriched outlet, comprises a primary cyclonic inertia separator comprising an expansion nozzle in which the fluid mixture is cooled to a temperature lower than 0 degrees Celsius by a substantially isentropic expansion and in which one or more swirl imparting vanes induce the fluid to swirl into a diverging outlet section which is equipped with a central primary condensables depleted fluid outlet conduit and an outer secondary condensables enriched fluid outlet conduit.

14. (Previously Presented) The fluid separation assembly of claim 13, wherein each primary cyclonic inertia separator comprises an expansion nozzle designed to accelerate the fluid mixture within the nozzle to a supersonic speed, thereby cooling the temperature of the fluid passing through the nozzle to a temperature lower than -20 degrees Celsius.

15. (Previously Presented) The fluid separation assembly of claim 13 comprising a plurality of primary cyclonic inertia separators of which the expansion nozzles are substantially parallel and equidistant to the central axis of the tubular section of the secondary separation vessel and of which the secondary condensables enriched fluid outlets are connected to secondary fluid injection conduits which intersect the wall of the tubular section of the secondary separation vessel at regular circumferential intervals and in an at least partially tangential direction, and which secondary fluid injection conduits each have a length less than 4 meters.

16. (Previously Presented) The fluid separation assembly of claim 1, wherein the gas cooling devices comprise chokes.

17. (Previously Presented) A method of separating condensable components from a fluid mixture in a multistage fluid separation assembly, the method comprising:

injecting the fluid mixture into a plurality of primary gas cooling devices in which the fluid mixture is expanded and cooled and condensable components are liquefied and/or solidified and in each primary gas cooling device a stream of condensables enriched fluid components is fed into a secondary fluid outlet; and

injecting the stream of condensables enriched fluid components into a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation and in which the condensables enriched fluid stream is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary mixture of liquefied and/or solidified condensables is induced by gravity and centrifugal forces to swirl in a downward direction alongside an inner surface of the tubular section of the vessel into a liquid collecting tank at or near a bottom of the vessel, in which tank the tertiary mixture of liquefied and/or solidified condensables is collected and heated to reduce the amount of solidified condensables and from which tank liquid and/or solidified components are discharged through one or more outlets;

wherein a plurality of secondary fluid injection outlets are connected at regular circumferential intervals to the tubular section of the secondary separation vessel, and

the enriched fluid outlets inject the condensables enriched fluid in an at least partially tangential direction into an interior of the secondary separation vessel.

18. (Previously Presented) The method of claim 17, wherein the fluid mixture is a natural gas stream which is cooled in the gas cooling devices comprising one or more primary cyclonic inertia separators to a temperature below 0 degrees Celsius thereby condensing and/or solidifying aqueous and hydrocarbon condensates and gas hydrates and the tertiary fluid mixture comprises water, ice, hydrocarbon condensates and gas hydrates and is heated in the tertiary fluid collecting tank to a temperature above 15 degrees Celsius to reduce the amount of gas hydrates, and from which tank low density hydrocarbon condensates are discharged through an upper liquid outlet and high density aqueous components are discharged through a lower liquid outlet.

19. (Previously Presented) The method of claim 17, wherein liquefied and/or solidified components are separated from the gaseous components by centrifugal force in the primary gas cooling device.

Evidence Appendix

US Patent 6,932,858

US006932858B2

(12) **United States Patent**
Nicol et al.

(10) **Patent No.: US 6,932,858 B2**
(45) **Date of Patent: Aug. 23, 2005**

(54) **VORTEX TUBE SYSTEM AND METHOD FOR PROCESSING NATURAL GAS**

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(73) Assignee: **Gas Technology Institute**, Des Plaines, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 145 days.

(21) Appl. No.: **10/649,991**

(22) Filed: **Aug. 27, 2003**

(65) **Prior Publication Data**

US 2005/0045033 A1 Mar. 3, 2005

(51) **Int. Cl.**[7] **B01D 45/12**; B01D 50/00
(52) **U.S. Cl.** **95/269**; 55/315; 55/343; 55/417; 55/459.1; 62/5
(58) **Field of Search** 95/269; 55/343, 55/315, 417, 459.1; 62/5

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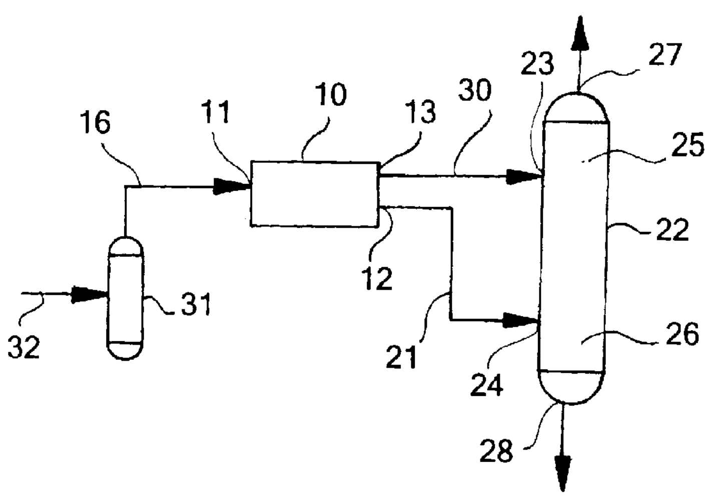
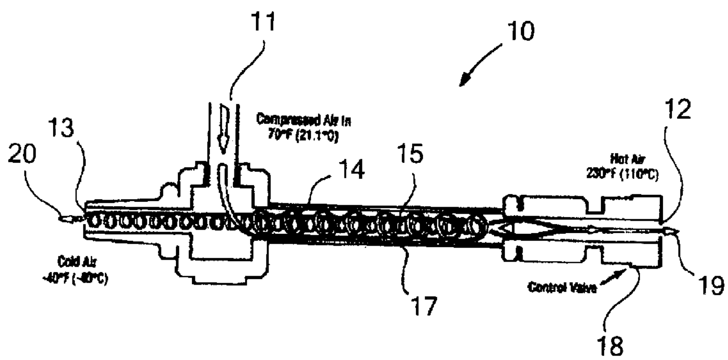
(74) *Attorney, Agent, or Firm*—Mark E. Fejer

(57) **ABSTRACT**

A method and system for processing of natural gas in which a gaseous natural gas stream which is made up of a mixture of hydrocarbons is introduced into a vortex tube, forming a hot fluid stream and a cold fluid stream. The cold fluid stream is introduced into the upper section of a distillation column and the hot fluid stream is introduced into the lower section of the distillation column, resulting in improved separation of the heavier hydrocarbon components in the natural gas stream from the lighter hydrocarbon components disposed in the natural gas stream.

13 Claims, 3 Drawing Sheets

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10
Compressed Air In
70°F (21.1°C)
12
13
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Hot Air
230°F (110°C)
Cold Air
-40°F (-40°C)
17
Control Valve
19
18

Fig. 1

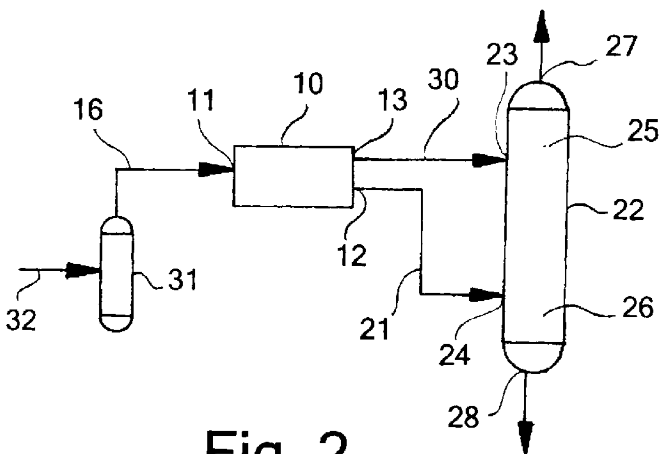

Fig. 2

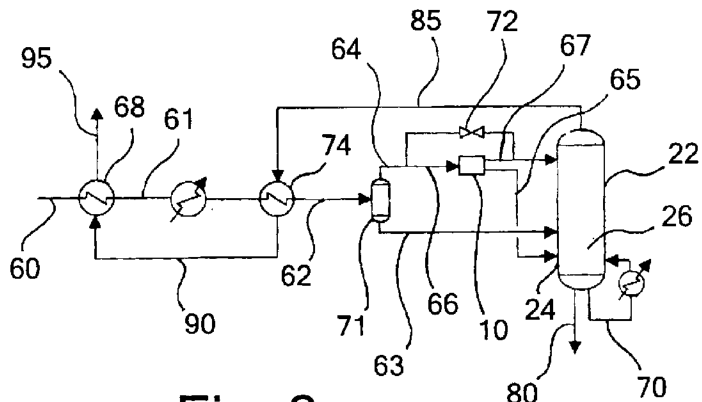

Fig. 3

VORTEX TUBE SYSTEM AND METHOD FOR PROCESSING NATURAL GAS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for processing natural gas to separate the heavier hydrocarbon components from the lighter hydrocarbon components typically found in produced natural gas. More particularly, this invention relates to the use of vortex tubes for processing natural gas streams.

2. Description of Related Art

Natural gas, as produced, typically comprises methane, ethane, propane, butane and natural gasoline. Excessive amounts of the heavier hydrocarbon components, e.g. propane, butane and natural gasoline, make the gas unsuitable for use as a gaseous fuel and create problems for gas transportation systems. In addition, the heavier components are usually more valuable when separated from the lighter components. Ethane value is sometimes higher in the gas stream and sometimes higher in the liquid stream.

It is, thus, frequently necessary to process the produced natural gas to separate the heavier hydrocarbon components from the lighter hydrocarbon components. Depending upon the component concentrations and current component values, processing natural gas can be very lucrative. Typically, component separation is carried out by the combination of refrigeration to condense the heavier components and distillation to remove the lighter components from the liquid stream. Refrigeration is often achieved by pressure reduction through a turbo-expander or a Joule-Thompson (J-T) effect control valve. The J-T effect control valve provides cooling of the gaseous stream by adiabatic expansion across a restriction.

A turbo-expander system is the most efficient and effective process for utilizing pressure drop to process produced natural gas. However, it is also expensive to construct, expensive to operate and somewhat inflexible with respect to product separation. The simpler J-T control valve system costs less to construct, costs less to operate and is more flexible with respect to product separation.

A vortex tube, also sometimes referred to as the Ranque Vortex Tube, the Hilsch Tube, the Ranque-Hilsch Tube and "Maxwell's Demon", is a static mechanical device that takes pressurized compressible fluid and derives a hot fluid and a cold fluid at a lower pressure. First discovered by George Ranque in 1928 and later developed by Rudolf Hilsch in 1945, the mechanics of why the Ranque-Hilsch effect separates a fluid into hot and cold parts through depressurizing are largely unknown, but empirical data validate that it is a measurable, repeatable and sustainable event. In operation, the pressurized compressible fluid is injected through tangential nozzles into a vortex chamber in which the compressible fluid is simultaneously separated into a fluid stream higher in temperature than the inlet stream and a fluid stream that is cooler than the inlet stream. One widely accepted explanation of the phenomenon is that tangential injection sets the pressurized compressible fluid stream in a vortex motion. This spinning stream of compressible fluid turns 90° and passes down the hot tube in the form of a spinning shell or vortex, similar to a tornado. A valve at one end of the tube allows some of the warmed fluid to escape. That portion of the warmed fluid that does not escape is directed back down the tube as a second vortex inside the low-pressure area of the larger vortex. This inner vortex loses heat to the larger vortex and exhausts through the other end as a cold fluid stream.

It is known to those skilled in the art that the vortex tube effect can be utilized to separate a multi-component hydrocarbon stream into hot and cold streams. It has also been shown that the hot stream exists in a somewhat richer state, that is, more heavy components than the cold stream, which results in a more efficient component separation than the conventional gas/liquid separator. U.S. Pat. No. 5,976,227 teaches a device for separation of liquid from a gas-liquid mixture comprising a vortex tube through which the gas-liquid mixture flows at speeds generating centrifugal forces with acceleration greater than 50 g, which cause liquid droplets to precipitate on the interior walls of the vortex tube. Concentric channels disposed in the tube wall of the warm end of the tube provide the means for the liquid removal. An outer casing encloses the warm end tube and serves to collect the liquids, which, in turn, are directed to a standalone separator. After removal of the liquids in the warm end tube, the warm and cold gas fractions of the vortex tube are recombined into the "conditioned" gas stream. Use of the vortex in a variety of applications are exemplified by U.S. Pat. No. 5,937,654, which teaches the use of a vortex tube for mixing water with chilled air to produce snow; U.S. Pat. No. 6,082,116, which teaches a vortex heater for transferring a vortex flow's heat flux to a separate gas flow in a system including a vortex tube for the purpose of preventing pilot gas freeze up at gas pressure regulation stations; and U.S. Pat. No. 5,483,801, which teaches a process for extracting vapor from a gas stream using a vortex tube expansion. See also U.S. Pat. No. 5,950,436 and U.S. Pat. No. 5,819,541 (method of beverage cooling/heating on vehicles), U.S. Pat. No. 5,911,740 (method of heat transfer enhancement in vortex tubes), U.S. Pat. No. 5,582,012 (method of natural gas pressure reduction on city gate stations), U.S. Pat. No. 5,561,982 (method for energy separation and utilization in a vortex tube operating at pressures not exceeding atmospheric pressure), and U.S. Pat. No. 5,327,728 (method of designing a vortex tube for energy separation).

Given the state of the art with respect to natural gas processing, it is desirable to improve the efficiency of natural gas processing, reduce the costs associated with natural gas processing, and provide more flexibility in product separation than conventional natural gas processing systems.

SUMMARY OF THE INVENTION

Accordingly, it is one object of this invention to provide a method and apparatus for natural gas processing.

It is one object of this invention to provide a method and apparatus for natural gas processing having improved efficiency over conventional natural gas processing systems.

It is a further object of this invention to provide a method and apparatus for natural gas processing which provides greater flexibility with respect to product separation than conventional natural gas processing systems.

It is another object of this invention to provide a method and apparatus for natural gas processing that is simpler in design and operation than conventional natural gas processing systems.

These and other objects of this invention are addressed by a system for natural gas processing comprising at least one vortex tube having a gaseous natural gas stream inlet, a hot fluid stream outlet and a cold fluid stream outlet, and at least one distillation column having a hot fluid stream inlet in fluid communication with the hot fluid stream outlet and having a cold fluid stream inlet in fluid communication with the cold fluid stream outlet. This use of the vortex tube effect in combination with a distillation column provides a sub-

stantial improvement in the efficiency of the natural gas processing system with respect to the separation of hydrocarbon components. In addition, there are no pressure or temperature restrictions. The only requirement is that the natural gas stream be in the gaseous state when it is introduced into the vortex tube.

The surprising result of utilizing a vortex tube for pressure reduction in combination with the typical equipment employed in a J-T control valve processing facility is that component separation is significantly enhanced by feeding the cold stream into the top of the distillation column and feeding the hot stream into the lower section of the distillation column. By virtue of this arrangement, the heat required in the bottom of the distillation column is reduced, resulting in a lower average temperature than with a J-T control valve system.

In accordance with the method of this invention for processing natural gas, a gaseous natural gas stream comprising a mixture of hydrocarbons is introduced into a vortex tube, resulting in the formation of a hot fluid stream and a cold fluid stream. The cold fluid stream is introduced into the upper section of a distillation column and the hot fluid stream is introduced into the lower section of the distillation column, thereby separating heavier hydrocarbon components disposed within the natural gas stream from lighter hydrocarbon components disposed in the natural gas stream.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of this invention will be better understood from the following detailed description taken in conjunction with the drawings wherein:

FIG. **1** is a schematic lateral view showing the basic principles of operation of a vortex tube;

FIG. **2** is a schematic diagram of the basic components of a system for processing natural gas in accordance with one embodiment of this invention; and

FIG. **3** is a schematic diagram of a system for processing natural gas utilizing one or more vortex tubes in accordance with one embodiment of this invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

One embodiment of a vortex tube suitable for use in the method and system of this invention is shown in FIG. **1**. As shown therein, vortex tube **10** comprises a tubular member **17** having a compressed fluid inlet **11**, hot fluid outlet **12** disposed at one end of tubular member **17** and a cold fluid outlet **13** disposed at the opposite end of tubular member **17**. Connected to the tubular member **17** proximate the hot fluid outlet **12** is a control valve **18**, which is used to control the amount of hot fluid **19** expelled from hot fluid outlet **12** of tubular member **17**, which, in turn, controls the amount of cold fluid **20** expelled from cold fluid outlet **13** of tubular member **17**.

From FIG. **1**, the principles of operation of a vortex tube can be seen. As shown therein, a compressed fluid, such as compressed air, is introduced through compressed fluid inlet **11** in a tangential manner whereby an outer vortex **14** is generated within tubular member **17** traveling in the direction of hot fluid outlet **12**. A portion of this stream of swirling compressed fluid, the amount of which is controlled by control valve **18**, is expelled as a hot fluid stream **19** from hot fluid outlet **12** of tubular member **17**. The remaining portion of the compressed fluid within tubular member **17** reverses direction towards cold fluid outlet **13**, forming a smaller vortex **15** within the outer vortex **14**. This stream is then expelled as a cold fluid stream **20** from cold fluid outlet **13** of tubular member **17**.

In accordance with the method and system of this invention, the compressed fluid is a hydrocarbon stream, such as natural gas, comprising a mixture of lighter and heavier hydrocarbons, the hot fluid stream comprises a portion of the heavier hydrocarbons separated out from the mixture and the cold fluid stream comprises lighter hydrocarbons. As used herein, the term "heavy hydrocarbons" refers to those hydrocarbons having more than a single carbon atom (e.g. ethane, propane, butane) and the term "light hydrocarbons" refers to those hydrocarbons having only a single carbon atom (e.g. methane).

FIG. **2** shows the basic elements of the system for processing natural gas in accordance with one embodiment of this invention, which basic elements comprise a gas/liquid separator **31** which is used to remove any liquid fluids that may be present in the initial fluid stream **32** for processing, thereby providing a gaseous stream **16** for input through compressed fluid inlet **11** into vortex tube **10**. It is a requirement of the method of this invention that the fluid stream introduced into vortex tube **10** is a gaseous stream. In accordance with a particularly preferred embodiment of this invention, a plurality of vortex tubes **10** are employed. Disposed downstream of the vortex tubes **10** and in fluid communication with the hot fluid outlet **12** and cold fluid outlet **13** of vortex tubes **10** is at least one distillation column **22** having a cold fluid inlet **23** in fluid communication with cold fluid outlet **13** disposed such that cold fluid stream **30** is introduced into an upper section **25** of distillation column **22** and having a hot fluid inlet **24** in fluid communication with hot fluid outlet **12** disposed such that hot fluid stream **21** is introduced into a lower section **26** of distillation column **22**. Distillation column **22** includes a gaseous fluid outlet **27** disposed proximate the top of distillation column **22** through which the lighter hydrocarbons are expelled and a liquid fluid outlet **28** disposed proximate the bottom of distillation column **22** through which the heavier liquid hydrocarbons are expelled.

FIG. **3** is a diagram showing a low temperature separation or liquefied petroleum gas process and system for processing of natural gas in accordance with one embodiment of this invention. As shown therein, heat is exchanged between an inlet stream **60** and stream **90** in heat exchanger **68** to a 5 or 10° F. approach temperature. The cooled inlet gas **61** may be chilled in a propane chiller (not shown) or it may flow directly to a gas/liquid separator **71**. If the gas is chilled, it will flow to heat exchanger **74** in which heat is exchanged with stream **85** to achieve a 10° F. approach. Stream **62** is a two-phase stream, that is liquid and gas. The liquid stream **63** is fed directly to the distillation column **22** or it may be combined with the hot stream **65** to be fed to the distillation column. Stream **64** will flow to stream **66**, which flows into a bank of vortex tubes **10**. In accordance with one embodiment of this invention, control of the vortex tube flow is accomplished by a manifold of N vortex tubes, each designed for 1/N of the design flow. Each vortex tube is designed for a fixed volume at the selected operating pressure. During start-up, flow is initiated through a bypass control valve **72**. When the flowing volume reaches the design volume of a vortex tube, a block valve opens to the inlet of the first vortex tube. As the volume continues to increase, the control valve opens until the total volume reaches the design volume of two vortex tubes. A block valve opens to a second vortex tube and the control valve closes. This sequence is repeated for each vortex tube until

full flow is achieved. For shutdown, the sequence is reversed. In accordance with one embodiment of this invention, control is achieved by a pressure control valve in fluid communication with each outlet of each vortex tube, which pressure control valves open and close the vortex tubes in sequence. The cold stream **67** from the vortex tube(s) combines with the flow, if any, from control valve **72**. The combined stream is then introduced into the top section of the distillation column **22**. The hot stream **65** from the vortex tube(s) is introduced into the distillation column **22** at hot fluid inlet **24** in the lower section **26** of the distillation column or it may be combined with stream **63** before being introduced into the distillation column. Stream **70** flows from the bottom of the distillation column through a heater and back into the column. Stream **80** delivers the liquid product to specification. The cold gas leaves the distillation column by means of stream **85**, exchanges heat with the incoming stream **60** and flows out as processed natural gas stream **95**.

It will be apparent to those skilled in the art that, although described herein in connection with the processing of natural gas, the method and system of this invention may be applied to a broad spectrum of gaseous streams comprising a mixture of lighter and heavier components for separation, and such applications are deemed to be within the scope of this invention.

While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for the purpose of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of this invention.

We claim:

1. A method for processing of natural gas comprising the steps of:

introducing a gaseous natural gas stream comprising a mixture of hydrocarbons into a plurality of vortex tubes, flow of said gaseous natural gas stream through each of said vortex tubes being controlled by a plurality of pressure control valves, each of said pressure control valves connected to a vortex tube outlet of a corresponding said vortex tube, forming a hot fluid stream and a cold fluid stream;

introducing said cold fluid stream into an upper section of a distillation column; and

introducing said hot fluid stream into a lower section of said distillation column, separating heavier hydrocarbon components from lighter hydrocarbon components disposed in said natural gas stream.

2. A method in accordance with claim **1**, wherein said mixture of hydrocarbons comprises hydrocarbons selected from the group consisting of methane, ethane, propane, butane and natural gasoline.

3. A method in accordance with claim **1**, wherein said gaseous natural gas stream is introduced into each of said vortex tubes in sequence.

4. A method in accordance with claim **3**, wherein said plurality of pressure control valves are opened and closed in sequence, thereby enabling sequential flow and sequential flow interruption through said plurality of vortex tubes.

5. A system for natural gas processing comprising:

at least one vortex tube having a gaseous natural gas stream inlet, a hot fluid stream outlet and a cold fluid stream outlet;

a flow control valve in fluid communication with each of said vortex tubes; and

at least one distillation column having a hot fluid stream inlet in fluid communication with said hot fluid stream outlet and having a cold fluid stream inlet in fluid communication with said cold fluid stream outlet.

6. A system in accordance with claim **5**, wherein each said vortex tube is designed for a volume of gaseous natural gas stream flowthrough that is dependent upon a set pressure drop across said vortex tube.

7. A system in accordance with claim **5**, wherein said flow control valve is a block valve having a valve outlet in fluid communication with said gaseous natural gas stream inlet.

8. A system in accordance with claim **5**, wherein said flow control valve is a pressure control valve having a fluid inlet in fluid communication with one of said hot fluid stream outlet and said cold fluid stream outlet.

9. A system in accordance with claim **5**, wherein said cold fluid stream inlet is disposed in an upper section of said distillation column and said hot fluid stream inlet is disposed in a lower section of said distillation column.

10. A method for processing a gaseous stream comprising the steps of:

introducing a gaseous stream comprising a mixture of components to be separated into a plurality of vortex tubes, flow of said gaseous stream through each of said vortex tubes being controlled by a plurality of pressure control valves, each of said pressure control valves connected to a vortex tube outlet of a corresponding said vortex tube forming a hot fluid stream and a cold fluid stream;

introducing said cold fluid stream into an upper section of a distillation column; and

introducing said hot fluid stream into a lower section of said distillation column, separating a first portion of said components from a second portion of said components disposed in said gaseous stream.

11. A method in accordance with claim **10**, wherein said gaseous stream comprises gas comprising heavier hydrocarbon components and lighter hydrocarbon components.

12. A method in accordance with claim **10**, wherein said gaseous stream is introduced into each of said vortex tubes in sequence.

13. A method in accordance with claim **10**, wherein said plurality of pressure control valves are opened and closed in sequence, thereby enabling sequential flow and sequential flow interruption through said plurality of vortex tubes.

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Related Proceedings Appendix

N/A

Related Proceedings Appendix

N/A